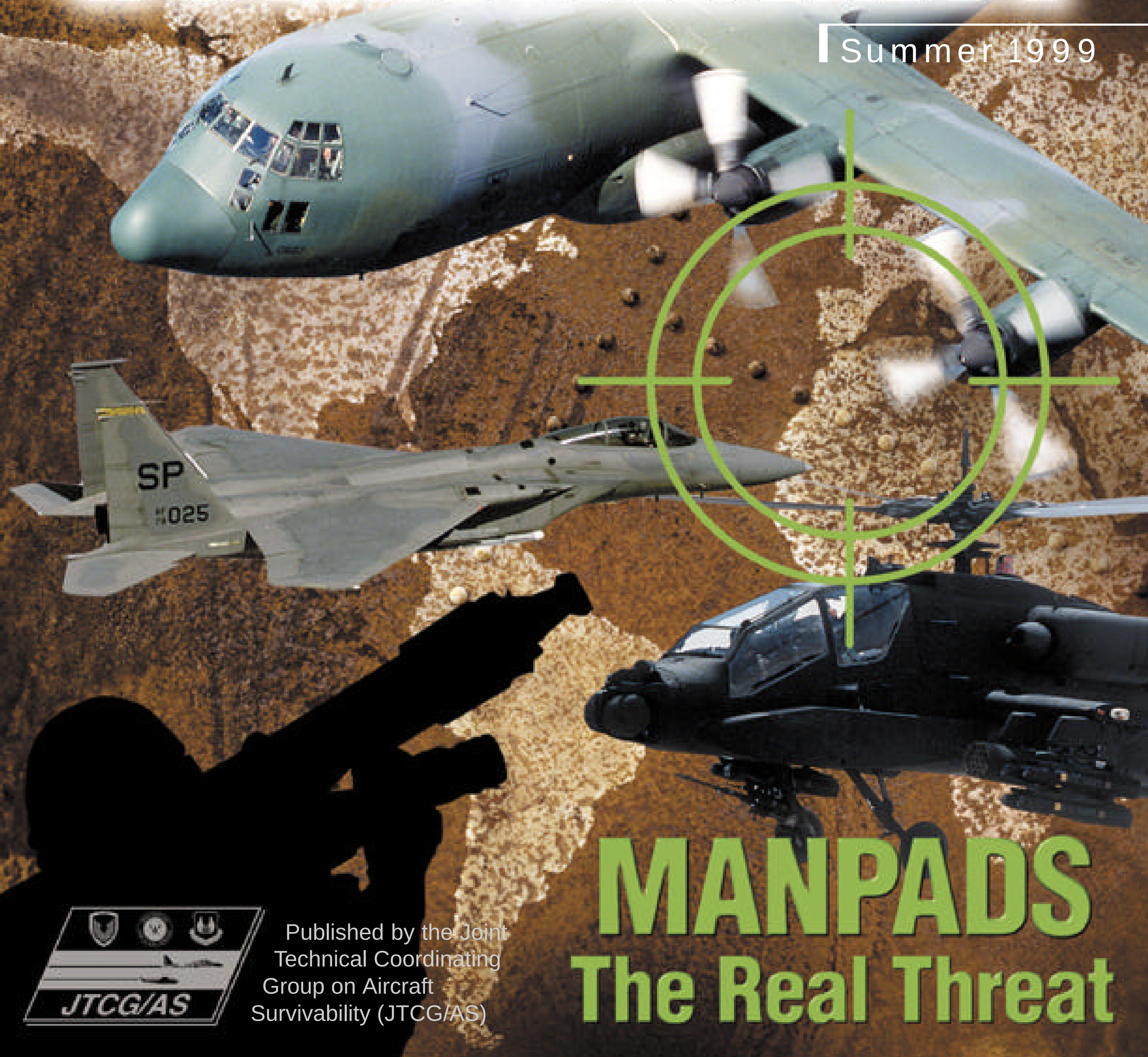
AIRCRAFT SURVIVABILITY

Summer 1999



MANPADS
The Real Threat

JTCG/AS

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Cover Design—Christina P. McNemar
The cover depicts the real threat posed by MANPADS such as the SA-14 Gremlin against U.S. aircraft, including transports, fixed-wing and rotorcraft. The aircraft shown are the Lockheed C-130 Hercules, the McDonnel Douglas F-15 Eagle, and the AH-64 Apache helicopter.

Contents

DoD Photo by SRA Jeffrey Allen, 1ST Combat Camera Sq.

Editor's Notes

Important changes are taking place that affect the JTCG/AS. On 7 June 99, the Secretary of Defense signed an action memorandum transferring, "key test and evaluation (T&E) functions" to OSD/DOT&E. Included in the transfer were the JTCG/AS and the JTCG/ME. The stated purpose was to streamline the T&E function and "strengthen the role of the DOT&E to support serious T&E with a view toward operations early in the life cycle of a program." OUSD(A&T) DTSE&E, which previously had oversight of the JTCG/AS, was disestablished by the same memorandum.

We've also recently experienced personnel changes on the Principal Member Steering Group, in our OSD sponsors' offices and in the Central Office. Dr. Steven Messervy is the new Army Principal Member. Dr. Messervy is Project Manager of the $2.4M Tri-Service Advanced Threat Infrared Countermeasures/Common Missile Warning System Joint Program Office located at Redstone Arsenal, Alabama. Prior to assuming his current position, he served as chief of program management of the Theater High Altitude Area Defense (THAAD) missile project office. We welcome Dr. Messervy to the JTCG/AS.

Col Steve Cameron, OUSD(A&T)DTSE&E/SA, who provided outstanding support to the JTCG/AS, was reassigned in June. His new assignment is Commandant of the Air Force Test Pilot School at Edwards AFB, CA. In addition, Dr. Al Rainis, OUSD(A&T)DS&TS/AW, another strong supporter of the JTCG/AS, retired in June. Dr. Rainis plans to remain in Northern Virginia for a year. The JTCG/AS acknowledges the strong support and contributions made by both Col Cameron and Dr. Rainis and wishes them success in their future endeavors.

In the Central Office, we welcome two additions to the staff since our last newsletter. Navy Capt Dale Stoehr is filling the Navy military officer position as a collateral duty. Capt Stoehr is assigned to the Naval Air Systems Command, Patuxent River, Maryland to code AIR-4.10.7, Health of Naval Aviation (HONA) office. In addition, we are glad to welcome Ms. Phyllis Drum to the staff as Administrative Assistant.

This issue of Aircraft Survivability is devoted to aircraft survivability against the Man Portable Air Defense Systems (MANPADS) threat. The focus is on vulnerability reduction—designing a more damage tolerant aircraft. We know that MANPADS are highly proliferated around the world, are relatively inexpensive, difficult to counter, easy to use and highly lethal. The Missile and Space Intelligence Center calls MANPADS, "The Real Threat". Survivability risks are influencing how and if aircraft are employed in combat. Battlespace is lost. Avoiding the threat is always preferred, however, to complement threat avoidance techniques, vulnerability reduction features designed into the aircraft offer a final line of defense. And history shows that MANPADS hits are survivable.

The JTCG/AS will soon be publishing the results of a study conducted at the request of the OUSD Office of the Deputy for Air Warfare, Strategic and Tactical Systems (OUSD(A&T) S&TS/AW). The study focuses on aircraft vulnerability to MANPADS threats and assesses combat and test data to determine if aircraft survivability can be enhanced through improved vulnerability reduction design techniques. The articles in this issue were derived from a MANPADS workshop held in December last year where vulnerability reduction techniques, methodologies and test facilities were topics of concern. The workshop was a part of the study.

We commend the articles on this important subject to your reading and welcome any feedback.

Joseph P Jolly

Aircraft Vulnerability to MANPADS Weapons

by Mr. Ronald "Mutz" Mutzelburg

A rather tired word puzzle bears the theme of my article: If a tree limb crashes in the center of a forest, and no living creatures are around, does it make a sound? The answer depends on the definition of sound. The dictionary says: "sound (n) is the sensation perceived by the sense of hearing." Clearly, according to the dictionary, the limb that crashes does not make a sound, even though it would if someone were listening.

If we are to meaningfully decrease the vulnerability of manned aircraft against Man Portable Air Defense Systems (MANPADS) weapons, we have to make sure someone is listening, not just in the room when we talk. Oratory and zealotry—while sometimes needed—have been known to "turn off" the listener. The crash and boom are still there, but no meaningful results.

MANPADS Threat to Manned Aircraft

MANPADS weapons are becoming the threat of choice against aircraft, but the vulnerability community has focused on bullet and fragment threats to aircraft since the Southeast Asia (SEA) conflict—with good reason:

- SEA losses were largely due to bullets and fragments.
- MANPADS testing facilities had not been developed.
- Methodologies to handle the MANPADS aircraft damage were inadequate.
- MANPADS aircraft hits were perceived to equal aircraft kills.

The last bullet is perhaps the most important. If the threat is so lethal that no meaningful fix can save the aircraft, why bother to minimize damage to an aircraft hit by a MANPADS missile?

An A-10 Thunderbolt II and F-16 Fighting Falcon fly in formation. (U.S. Air Force photo by Master Sgt. Rose Reynolds.)

Currently, we emphasize avoiding hits to the aircraft. We are pursuing susceptibility reduction in a variety of ways:

- Radio frequency (RF), infrared (IR) and acoustic signature reduction to minimize lock-on of the missile system
- Speed and super-agility to outpace a missile
- Standoff attack capability to minimize opportunities for the threat system to engage the aircraft
- Countermeasures to spoof the in-flight missile.

These are great efforts: don't stop! However, whatever our smart folks do, other smart folks seek to undo. Maybe we can stay ahead of them, maybe not. I feel that we would be wise not to neglect vulnerability reduction, just in case our aircraft gets hit.

Working with the Deputy Director, Resources and Ranges, I asked the Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS): What can be done, in aircraft design or retrofit, to reduce the lethality of a striking IR missile?[1] The corollary to this question is, are current vulnerability reduction techniques adequate, or are new ones needed given the large kinetic energy of the missile body, or some synergistic effect? The answers to these questions will probably depend on the specifics of a given aircraft or, at least, on the class of aircraft—as requested in the tasking memorandum.

What Is a Solution?

As always, the solution is probably more money and people. We need new methodologies to assess aircraft MANPADS vulnerability, testing data to validate the models, and—perhaps most important—design guidelines so that the developer can "hear" what the community is saying.

The environment for new programs—money and people—is *very* hostile. Starting a new initiative is very difficult. If the community concludes, in answer to my questions, that appropriate work must be done, the funds will come only at the expense of stopping, or slowing, something already under way. The affected function probably has constituents. To overcome the resistance, arguments will have to be strong.

How Should We Address the Problem?

The expert group convened by the JTCG/AS must develop compelling—and concise—arguments to expand MANPADS vulnerability reduction efforts, if warranted. The last phrase is important: What is the potential payoff? Why should a resource sponsor care, given his or her other needs in a very constrained environment?

And we must be complete and fair! Options to reduce aircraft vulnerability seldom are without some side effect. The identification of vulnerability reduction design or retrofit options should include the costs of exercising the options. This practice would help the user make informed choices during the tradeoff analyses of cost as an independent variable[2] that accompany a new design or major retrofit.

Conclusion

We must make sure that our results can be communicated, and understood, by folks outside of the technical vulnerability community. Assuming that the study now under way *strongly* justifies more efforts to reduce aircraft MANPADS vulnerability, we must package the results appropriately. The final product of the study must clearly say to nonspecialists—

- What is the benefit (roughly) of reducing aircraft MANPADS vulnerability
- What is the cost (roughly) to do this?

We can work together to make sure that the design process hears our (good!) story. We need buy-in from a variety of folks. Provide the good story, and I will walk the briefing trail with you to increase the likelihood that the results are "sound." ■

A USAF F-117A Nighthawk on it's way home. (U.S. Air Force photo by Tech Sgt. Jack Braden.)

Endnotes

1. Memorandum for Chairman, Principal Members, Joint Technical Coordinating Group on Aircraft Survivability, from Deputy Director, Air Warfare, February 11, 1998.
2. USD(A&T) Memorandum, "Reducing Life Cycle Costs for New and Fielded Systems," December 4, 1995.

About the Author

Mr. Mutzelburg received a B.S.I.E. from Wayne State University in 1968 and M.S. in Industrial and Systems Engineering from Ohio State University in 1974. He is currently the Deputy Director for Air Warfare within the Office of Strategic and Tactical Systems, Under Secretary of Defense for Acquisition & Technology. As such he is responsible for acquisition oversight for the B-1, B-2, C-17, F-22, F-18, JSTARS, numerous air-to-air and air-to-ground weapons and numerous other aeronautical programs. He may be reached at mutzelre@acq.osd.mil.

Losing Low Altitude Battlespace

The MANPADS Challenge

by Rear Admiral Robert H. Gormley, U.S. Navy (Ret)

Operation Allied Force, the NATO air campaign against Yugoslavia, reminded us just how much operational concepts and employment of new weapons technology have evolved since the 1991 Gulf War. And also, how political constraints on military commanders, combined with the anticipated lethality of an enemy's integrated air defense system and large numbers of man-portable air defense systems (MANPADS), can dictate U.S. tactics and influence outcomes.

The reality today seems to be that, absent a pressing need to risk Vietnam-level aircraft attrition rates (1% in NE Sector) and attendant aircrew losses, we are electing to relinquish daytime air battlespace below 15,000 feet to any enemy possessing a significant number of MANPADS and rapid fire AAA weapons. This was certainly so during Operation Allied Force. Why? Because low altitude operations were not seen as essential to achieving mission success and, more importantly, support for the bombing by the public in Europe and the U.S. would likely have eroded sharply had we lost three or so aircraft a day, even for a brief period.

Fortunately, laser and satellite (GPS)-guided weapons enabled our strike aircraft to remain at higher altitudes and still deal very effectively with fixed targets, subject, in the case of laser-guided weapons, to constraints imposed by cloud cover. On the other hand, attacks against mobile units and armed reconnaissance patrols seeking targets of opportunity were limited, as were operations of Apache attack helicopters. Only the A-10, an old, but nevertheless robust, low-vulnerability design, was said to be suitable for flight at lower altitudes during daylight hours.

But what about situations where operations in MANPADS/AAA-protected low altitude battlespace cannot be avoided or, indeed, may be mandated during a critical engagement—close air support, urgent priority strikes under cloud cover, armed reconnaissance, helicopter operations? This prospect conflicts with the apparent trend, noted above, of ceding the battlespace, below say 15,000 feet, to the enemy during the day. And it brings to mind questions that merit answers:

- Are our future aircraft to be wholly dependent for their combat survivability on hit avoidance measures such as low signatures, countermeasures, stand-off weapons, and smart tactics? Or should some or all be made more damage-resistant in the event they are hit by enemy fire?

- Are vulnerability reduction features and technologies being given appropriate consideration during the design of new combat aircraft?

- If damage resistance is not to be a design imperative and we anticipate only stand-off attacks launched from outside low altitude battlespace, are supersonic speed and agility needed in future tactical fighters? Or should we buy lower cost, subsonic "aerial trucks," in essence, long endurance platforms that carry big loads of stand-off weapons, both air-to-air and air-to-surface?

- What is the impact of the seeming abandonment of low altitude battlespace on the manned versus unmanned aircraft debate? Should unmanned programs be accelerated?

- What are the prospects in future conflicts for the inherently slow, low-flying rotorcraft on which both Army and Marine Corps operational concepts are heavily dependent? Can land forces be effective if daylight air operations, including troop lift, are sharply constrained by MANPADS and AAA? Are the two services facing up to this awesome challenge?

- And finally, will we continue to "own the night" at low altitudes? Is there any prospect that the nowubiquitous daylight MANPADS threat may spread to the night hours?

Answers to these and related questions turn on what can be done about the MANPADS threat and how it will evolve. Avoiding a missile hit is clearly the preferable course, but the solution here is proving to be costly and technically challenging. So, it makes sense to explore what might be done to improve the survivability of aircraft hit by MANPADS missiles. In this regard, the limited combat and test data available suggest that a hit does not always equate to a kill, but that the outcome is heavily contingent on the type of aircraft and its design. Here, the A-10 and F/A-18 at the top, and the AV-8B at the bottom, are examples at opposite ends of the fixed-wing vulnerability scale.

The Combat Survivability Division of the National Defense Industrial Association (NDIA) has long maintained a position that both susceptibility reduction (hit avoidance) and vulnerability reduction (damage resistance/tolerance) merit equal consideration during formulation of operational requirements and subsequent aircraft design and development. Recently, in response to worries of some association members about what they perceive as a general lessening of appreciation for vulnerability reduction, the Division's Executive Board commissioned a study to inquire into the matter. This study has been completed and its findings will be forwarded to Government officials later this year.

NDIA has, for some time, been concerned about the increasing MANPADS threat. For this reason, we are pleased to note, and strongly support, the current DoD-directed MANPADS project being conducted by the Joint Technical Coordinating Group on Aircraft Survivability, which is looking at how vulnerability of an aircraft to a MANPADS missile hit might be reduced. And to give added emphasis to this crucial subject, NDIA's survivability symposium program in the year 2000 will focus on the theme of combat air operations in low altitude battlespace.

In summary, the MANPADS challenge is about battlespace—both using it and losing it! Clearly, the threat is serious and has already begun to degrade tactical flexibility and the overall combat effectiveness of U.S. air and land forces. Erosion of low altitude battlespace must be arrested and lost space restored. Yes, this challenge is indeed formidable, but it is one that must be met. ■

RADM Gormley at recent symposium. He is Chairman of NDIA's Combat Survivability Division and may be reached at 650-854-8155.

EO/IR SAMs—A Pilot's Perspective

by Major Kevin Iiams, USMC

As a tactical pilot, I have changed my view over the years of the EO/IR SAM from seeing it as a planning nuisance to seeing it as a formidable, reputable threat. Early versions of the weapon system were few in number and did not possess the kinematics or the IRCCM capability to engage a modern fighter attack aircraft. This situation obviously changed, as the EO/IR SAM's capabilities grew and the demand for this inexpensive yet highly effective form of air defense caused dramatic increases in production and proliferation. From an attack pilot standpoint, the EO/IR SAM has become, to quote the EO/IR SAM division at DIA/MSIC, "The Real Threat."

An aircrew's perception of the threat and their response to it are based on the efforts to exploit these systems and to enhance the survivability of the aircraft and aircrew. Whereas our aircrew perception of radar SAM engagement is based primarily on electronic radar warning receivers, our perception of the EO/IR SAM is based mainly on the visual spectrum. As pilots we use our eyes, or our wingman's eyes, and situational awareness to determine our engagement status. Since current EO/IR systems provide little, if any, warning of engagement, it is paramount for the aircrew members to be visually aware of their environment and critical for them to acquire any threats of this type. Visual acquisition combined with a comprehensive knowledge of the threat will allow the aircrew to accurately assess the status of a threat missile in flight and determine the appropriate response. This, however, can be an almost impossible task at times, given the growing competition inside the cockpit for the pilot's attention.

Combat loaded F/A-18 Hornet from Strike Fighter Squadron Nine Four (VFA-94). The aircraft carries AIM-9 Sidewinder shor t range, and AIM-7 Spar row medium range air-to-air missiles, and one laser guided bomb. (U.S. Navy Photo by Lieutenant Steve Lightstone.)

Tactics against the EO/IR SAM threat vary based on type of aircraft and its capabilities but generally fall into one of three categories: avoidance, maneuver, or countermeasure/expendables. Each of these categories can be further divided into preemptive and reactive tactics. Reactive tactics are measures taken by the aircrew to defeat a system that is in flight. These tactics have mixed success. Although a timely response to an acquired threat is typically successful, we know from statistics that it is the unseen shot that will be the fatal one. You can't react to what you don't see, and with cockpit tasking growing with each new heads down weapon or subsystem, aircrews are seeing less and less of what is outside the cockpit. That is where preemptive tactics—tactics designed to prevent weapon employment or possibly defeat an engaged system—come into play. For those critical portions of the flight in which the aircrew are heavily tasked, and thus more likely to

Post flight assessment of EO/IR SAM damage during Desert Storm.

miss a visual acquisition, preemptive tactics provide a measure of protection.

Without a doubt the EO/IR SAM is an extremely potent weapon system. So why would supposedly intelligent aviators purposely expose themselves to this threat? Well, if we don't have to, we won't. However, for the majority of the missions that tactical bombing platforms perform (close air support and armed reconnaissance), we are likely to be forced into a portion of the threat envelope. This is inevitable for a number of reasons. When employing ordnance in close proximity to friendlies, or in an unknown target environment, target acquisition is vital. But given the limits of the human eye, aircrew cannot expect to detect and acquire tactical sized targets beyond about 2 nautical miles (12,000 feet). Target recognition will occur at even shorter ranges. Thus, it would be necessary to get closer to the target than safety concerns alone would dictate. In addition, the professionalism of aircrews, not to mention real world rules of engagement (ROE), don't tolerate much error or risk of "friendly fire" casualties. So, aircrews will do what it takes to kill the bad guys and not our Marines and soldiers. That may mean aircrew members must risk the aircraft and their lives by going into the threat envelop; if so, it's time to earn the flight pay.

This commitment to the mission is all that much easier to sustain when the aircrew feel that the majority of the risk to self and aircraft has been mitigated, and that aircrew performance is the only remaining factor. Against the EO/IR SAM threat, aircrews count on detailed exploitation and system knowledge of the threat to develop viable preemptive and reactive tactics. We also depend on the robust survivability engineering of our aircraft since we know that we will be engaged, that the likelihood of seeing every SAM will be small, and that we will take hits. ■

About the Author

Major Iiams, USMC is head of the F/A-18 Division of Marine Aviation Weapons and Tactics Squadron One at MCAS Yuma, Arizona, and is the EO/IR SAM and AAA Instructor. Major Iiams graduated from the U.S. Naval Academy with a B.S. in General Engineering. He has flown 2300 flight hours in the F/A-18, F-5, and training aircraft. He is credited with 41 combat missions in the F/A-18 during Desert Storm, and sustained combat damage due to EO/IR SAM. He may be reached at iiamsk@yuma.usmc.mil.

Battle damaged F/A-18. This aircraft flew 250 nm to home base and was returned to service in under 48 hours.

Editor's Note: Major Iiams has recently been reassigned and is attending professional military education in residence.

National MANPADS Workshop
A Vulnerability Perspective

by Mr. Greg Czarnecki

The National MANPADS Workshop was held 15–17 December 1998 at the Redstone Arsenal, Alabama to bring the nation's talents to bear on aircraft-MANPADS (Man Portable Air Defense System) vulnerability issues. The workshop was cohosted by the Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS) and the Defense Intelligence Agency's Missile and Space Intelligence Center (MSIC). Workshop objectives were to: 1) gather and exchange information concerning aircraft-MANPADS encounters, 2) compile a roadmap of current MANPADS vulnerability reduction activities, and 3) identify MANPADS-capable vulnerability reduction solutions.

Dr. Patricia Sanders, OUSD(A&T) DTSE&E, presented the keynote address. Among the workshop highlights were presentations by three Desert Storm pilots whose aircraft were hit by MANPADS missiles. Each discussed their low altitude operations (required for target identification) and the experience of being hit without warning. Throughout the 3-day workshop, government and industry speakers described MANPADS proliferation and lethality, susceptibility reduction limitations, and the need to incorporate a rational measure of vulnerability reduction into aircraft designs. Briefing topics and breakout sessions concentrated on vulnerability reduction techniques, assessment methodologies, and test facility capabilities. Whatever the subject, discussions throughout the workshop emphasized the following common messages:

1 MANPADS threats are lethal and have proliferated worldwide in large numbers. This shoulder-launched weapon system represents the most prolific SAM threat to modern aircraft.

2 A MANPADS hit does not equal a kill. For military and commercial aircraft, the probabilities of a kill given a hit ($P_{K/H}$) are 51 percent and 70 percent, respectively. Given hits, most kills result from subsystem vulnerabilities.

3 MANPADS survivability lessons learned from Desert Storm include:

- Fly at night and at very high altitudes
- Keep flight control hydraulics away from likely hit locations
- Separate fuel systems from likely hit locations
- Incorporate fluid shutoff mechanisms in the aft portions of engines
- Use extended nozzles.

4 Helicopters have a more difficult time avoiding detection and outmaneuvering the MANPADS threat than do fighter aircraft. Pilots must fly at low altitudes to identify targets and successfully complete their mission with substantial certainty. Of all factors, the engine's location and critical subsystems redundancy in current aircraft designs influence survivability the most. Single engine aircraft can be made survivable if vulnerability reduction features are incorporated early in the design stage.

5 MANPADS weapons offer an economical means of destroying high-value targets, making them the weapon of choice in Third World countries and terrorist organizations. Terrorists armed with MANPADS represent the number 1 threat to transport aircraft. Large signatures (visual and IR), slow speed, and lack of maneuverability, make transport aircraft easy MANPADS targets. Vulnerability reduction features are needed to enhance survivability.

6 Participants in the vulnerability reduction techniques breakout session called for expanded test databases and improved assessment methodologies to support development of many MANPADS-capable features. In addition, they said vulnerability reduction techniques required input from the susceptibility reduction community to ensure attainment of optimal survivability without detracting from stealth or countermeasures. They emphasized that all proposed MANPADS-capable vulnerability reduction techniques offered the prospect of improved aircraft survivability through implementation of currently available technologies. Examples included:

- Incorporating sacrificial nozzles and structure
- Locating IR sources in less vulnerable areas
- Locating flight control systems away from IR sources
- Hardening or shielding critical components around IR sources
- Thermally managing engines (having outboard engines run hotter than inboard engines)
- Thermally managing IR sources to direct seekers to the least vulnerable location
- Using material systems that reduce the probability of a fuse functioning as intended
- Increasing the engine's compressor stall margin before missile impact
- Decreasing vulnerabilities associated with ram, fire, and explosion
- Developing engine rotors capable of rebalancing after sustaining damage
- Developing fail-safe structure.

7 Participants in the vulnerability assessment methodologies session added they needed an enhanced MANPADS test database to support development of improved assessment methodologies. They reported that models were incapable of predicting surface-to-air missile hit locations and called for specific improvements in target IR signature models and threat-in-the-loop software. They stressed that modeling requirements need to drive tests performed and data collected. Participants in the vulnerability test facilities and capabilities session stated that current MANPADS test facilities were generally adequate and no major investments were required. They noted exceptions relative to shotline control and handling of large, transport-sized aircraft as targets.

In summary, MANPADS have become a highly proliferated and lethal threat to all types of aircraft. Countermeasures are difficult to achieve and may not keep up with this evolving threat. The prospect of MANPADS hits has curtailed battlespace, particularly for daytime and low altitude operations. Nevertheless, all aircraft (even stealth and highfliers) remain susceptible to MANPADS positioned near airfields. To remedy this situation and improve overall survivability, MANPADS-capable vulnerability reduction features must be integrated into aircraft designs along with countermeasures. Designing in a proper mix of susceptibility reduction and vulnerability reduction features, will ensure aircraft an optimal level of survivability at the lowest possible cost. ■

About the Author

Mr. Czarnecki received his B.S. in Civil Engineering and his M.S. in Materials Engineering from the University of Dayton. He is a civilian with the Air Force Research Laboratory Air Vehicles Directorate, Survivability & Safety Branch. Mr. Czarnecki specializes in Aircraft survivability, concentrating on impact physics of composites, projectile-induced hydrodynamic ram, and aircraft vulnerability reduction to the MANPADS shoulder-launched missile threat. He is a member of the JTCG/AS Vulnerability Reduction Subgroup and Chairman of that organization's Structures & Materials Committee. He may be reached at gregory.czarnecki@va.wpafb.af.mil.

MANPADS Combat History

by Mr. Kevin Crosthwaite

The first MANPADS, the U.S. Redeye, became operational in 1967. The Soviet SA-7 followed in 1968. Both weapons relied on IR tracking, a small warhead, and contact fuzing and were employed by teams of two soldiers. MANPADS quickly became a successful new class of air defense threats.

Incident Highlights

South east Asia (SEA)— Allied operations in SEA relied heavily on air power, and the U.S. lost thousands of aircraft of all types. The primary threats were small arms, AAA, and RF SAMS. In 1972, as U.S. involvement waned, SA-7 MANPADS were introduced as a new threat. SA-7s hit and damaged 26 U.S. aircraft, killing 20. Only three of the 26 aircraft were jets, which gave rise to the theory that SA-7s could engage only slow-moving targets. As a countermeasure against the MANPADS threat, U.S. Forces deployed flares, both preemptively and after seeing SA-7 rocket plumes. The flares worked effectively against early MANPADS; however, later versions of the SA-7 used a smokeless propellant, which made the flare method less effective.

Yom Kippur— In 1973, Egypt and Syria attacked Israel. The Israelis quickly launched a counterattack, but were repelled with heavy losses. Eighteen days later, the Israelis prevailed. MANPADS caused only a small portion of the Israeli losses in the Yom Kippur war. MANPADS were not a dominant factor in this conflict because of a simple but effective countermeasure. The Israelis correctly determined that their primary ground attack aircraft, the A4, was the most susceptible to SA-7 attacks. Their simple fix was to attach a tailpipe extension on the A4, which effectively moved the likely SA-7 impact point away from the single engine and other flight-critical components in the aircraft's tail.

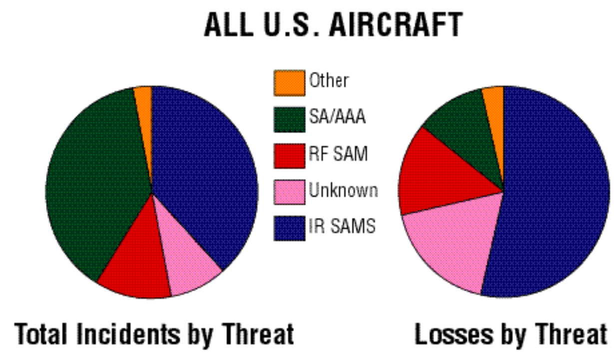

Figure 1. Desert Storm Damage by Threat

Afghanistan— In 1979, the Soviets invaded Afghanistan with several airborne and armored divisions, and were soon able to establish a local puppet government. However, a guerrilla war with native Mujahideen could not be won quickly in the rough mountainous countryside, despite superior Soviet airpower.

In 1986, modern MANPADS (Blowpipe and Stinger) were supplied to the Afghan rebels, and it was reported that 340 Stingers shot down 269 aircraft. Although the Soviets employed IR jammers, engine exhaust suppressors, and flares, the MANPADS threat greatly influenced Soviet tactics. For example, TU-16 and SU-24 bomber pilots had become accustomed to delivering their ordnance from relatively low altitudes of 2,000 to 4,000 feet. Considering the new MANPADS threat, pilots began to fly at about 10,000 feet, decreasing their accuracy. Likewise, the Mi24 and Mi25 pilots engaged in direct combat less often, and when they did, they flew low and fast over their targets. Also, to avoid the low-altitude danger posed by MANPADS, Soviet pilots began making high-gradient climbs at takeoff to reach safe flight levels quickly. Although combat losses dropped by using these new takeoff procedures, accident rates rose.

Desert Storm— In 1991, U.S. air power was used decisively against Iraq. Aircraft were sent on a wide variety of missions, and overall aircraft losses were much less than expected. Figure 1 shows a breakdown by threat of all aircraft damaged in combat and also the subset of these aircraft that were lost.

It is obvious that IR SAMS killed the most aircraft. When the relative probability of kills given a hit is plotted, the IR SAMS and RF SAMS stand out as the most lethal threats encountered in Desert Storm.

Other Conflicts— MANPADS have also been used in smaller conflicts. The British Blowpipe was credited with killing eight light attack Pucara aircraft during the Falklands war. MANPADS have been used against U.S., French, and Israeli aircraft in Lebanon. They have been used in Eriteria against Ethiopians, by Kurds against Turkey, and by all sides in Bosnia. North Korea allegedly used a MANPADS against a U.S. helicopter straying across the DMZ. Even during Urgent Fury in Grenada, where the U.S. held air supremacy, Stinger teams were deployed with the U.S. ground forces for additional air defense protection.

Civil— In November 1975, a MANPADS was launched at and damaged a Skyvan aircraft over Angola; this was the first recorded engagement of a civil aircraft. The most recent incident was the 10 October 1998 shoot down of a Boeing 727 in Congo. The intervening years have witnessed 34 such incidents. Twenty four of these aircraft were lost, with more than 585 casualties. Most of these incidents occurred in hot war zones, and the aircraft were engaged in quasi-military missions, such as flying in aid or supplies, evacuating civilians, or transporting troops.

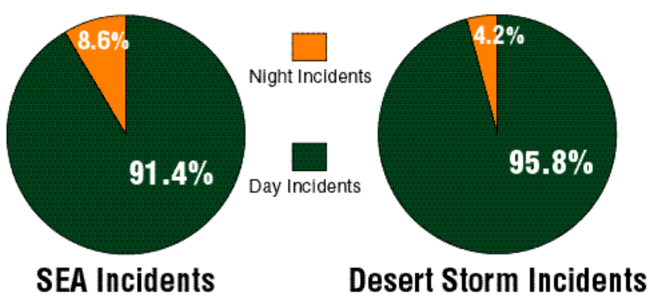

Figure 2. Day vs. Night MANPADS Incidents.

These 34 incidents involved many types of aircraft and MANPADS. SA-7s were the most common weapons used, but SA-16s and Stingers were also used. Controlled tests in the U.S. have shown that each of these MANPADS is fully capable of tracking and locking onto commercial aircraft at reasonable distances while they are landing or taking off.

MANPADS have not been used against commercial airline traffic, but this is a real possibility. It is difficult to estimate the tragic consequences that could result if a civil aircraft is shot down by MANPADS. To illustrate, on 6 April 1994 an aircraft carrying the President of Rwanda was shot down, killing all passengers. This act ignited a genocidal civil war in which more than 500,000 Tutsis and moderate Hutus were massacred. Several thousand survivors became refugees. Such awful consequences are a real danger of MANPADS.

Combat Data Analysis

SURVIAC has data on each MANPADS incident in SEA and Desert Storm, including aircraft type and serial number, date, time, location, aircraft speed, altitude, mission, and threat engagement geometry. Attack aircraft and helicopters were most often engaged by MANPADS during these conflicts because their missions, such as close support and air interdiction, brought them to lower altitudes. Because the type of aircraft that perform such missions face the greatest risk of attack by MANPADS, these aircraft should be the focus of vulnerability reduction efforts.

As Figure 2 shows, MANPADS attacks occurred predominately during the day, although the systems are not technically limited to daytime use. In fact, the IR seeker should work best at night, given the greater contrast between a hot target and a cool background.

The limitation, therefore, appears to stem from the MANPADS teams' inability to see their targets at night. In comparing day and night attacks across all threat types during Desert Storm, the aversion to night operations was peculiar to MANPADS. One reason might be that the MANPADS teams were disbursed and isolated, often with only a radio for command and control and early warning. These teams also usually acquire their targets by eyesight, and usually do not have night vision goggles. Increasing availability of night vision devices could significantly enhance MANPADS night operations. However, improved system-wide command and control and early warning might still be necessary for the these teams to reach full effectiveness.

To determine the frequency of MANPADS engagements, it is important to follow the action on the battlefield. In the early phase of an air campaign, missions can be well planned

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Low Vulnerability Technologies

Building a Balanced Approach

by Mr. Anthony Lizza and Mr. Greg Czarnecki

Real world experiences highlight the importance of aircraft survivability. The 5,000+ U.S. fixed and rotary wing aircraft lost during Vietnam made it clear that survivability had not always been given sufficient emphasis—especially during design.

In the years since Vietnam, the JTCG/AS and others have made significant progress in developing a host of technologies, from fire detection and suppression to ballistic-tolerant structures. Most of these low vulnerability (LV) technologies have focused on designing aircraft to survive hits from AAA and single missile-fragment threats.

Over the same period, the introduction of stealth technology turned the survivability community's attention toward the benefit of susceptibility reduction (i.e., low observables [LO] and countermeasures [CM]). These revolutionary technologies, so clearly demonstrated in Desert Storm, have made it possible for LO aircraft to go virtually undetected during combat operations, significantly reducing the likelihood of hits from RF-guided threats.

MANPADS Threat

Yet today, a host of emerging missile threats present new and significant challenges to current aircraft designs. Among them, the MANPADS threatens not only combat aircraft (fighters/bombers/helicopters), but also vital military transports, tankers, and command-and-control assets traditionally thought to operate out of harm's way. MANPADS are a hit-to-kill threat that has now proliferated worldwide. MANPADS ready availability to all comers with cash in hand increases the survivability challenge. Peacetime survival capabilities are becoming as important as those required in war.

Avoiding the threat through the use of signature reduction, CM, and tactics is the preferred solution. No pilot wants to get hit! Still, today's CMs depend heavily on situational awareness and timely knowledge of the inbound threat. Advanced guidance systems make the MANPADS threat extremely difficult to detect, allowing virtually no time for the pilot to react. In fact, Desert Storm events demonstrated that most often a pilot's first indication of being targeted occurred after the aircraft was hit. In addition, advanced missile seekers may detect aircraft once thought "invisible" to these systems.

Desert Storm AV-8B loss due to MANPADS

Tactical mission doctrine already dictates that combat operations are best conducted at night—on the premise that "if you can be seen, you can be hit." Daytime "battle space" is therefore being relinquished because evolving threats pose unacceptable risks. Extending well above 10,000 feet, the present threat envelope, MANPADS threats have forced air operations to ever-higher altitudes, and made weather and clouds an increasing factor in mission planning. Moreover, regardless of the threat avoidance measure, aircraft of all types remain highly susceptible to these portable, shoulder-launched, heat-seeking threats during takeoffs and landings.

The Need for Low Vulnerability Technology

Increasing proliferation and lethality of MANPADS and growing concern that existing susceptibility reduction techniques alone may not provide adequate protection raise the question, "What LV features *could* enhance aircraft survivability and regain battle space?"

LV techniques and designs can provide a necessary line of protection and contribute immensely to overall survivability of aircraft of all types. Unfortunately, before these life saving technologies can be considered, the LV community must overcome two false perceptions: 1) a hit equals a kill, and 2) nothing can lower aircraft vulnerability. Many events prove that aircraft can and do survive MANPADS hits. LV technologies and design features often contributed critically to a damaged aircraft's successful return.

Determining which onboard LV features lend themselves to aircraft survival after a hit requires full understanding of the threat. Hit-to-kill MANPADS weapons differ greatly from bullet and single missile fragments—and the community has yet to fully characterize the differences.

Compared with AAA, MANPADS delivers perhaps 20 times the explosive charge weight and orders-of-magnitude more mass. Combined with the large variety of MANPADS missile types and fuses available, these factors make it extremely difficult to predict potential damage—a critical component in developing LV technologies.

Secondly, the community must analyze which "zones" (structural, fuel system, propulsion, flight systems, etc.) are most prone to failure by aircraft type (transport, tactical, rotary) and mission (first strike, air superiority, and CAS).

Desert Storm results provide the opportunity to learn lessons, because some aircraft designs proved less vulnerable than others. What built-in LV techniques prevented losses? Which features were lacking in aircraft that were lost? This analysis may be simplified by the historically high probability of MANPADS strikes at specific hot-spot locations. Because most fielded MANPADS weapons incorporate older technologies, the LV community should concentrate its attention on and around the common hit locations. Knowledge of likely hit locations may reduce the need for full LV protection of the entire aircraft.

However, as improved seekers are developed, they increase the randomness of hit locations. **Moreover, the community cannot ignore future threats.** Directed energy, once tomorrow's threat, is already being used in some applications. As its use evolves, and new threats emerge, the community must not limit its view simply to immediate issues.

Desert Storm F/A-18 survives MANPADS hit.

Summary

A combination of susceptibility reduction and LV features optimizes survivability. Susceptibility reduction features reduce the number of potential hits and remain an essential element of aircraft defense. But even if susceptibility reduction techniques work perfectly, hits will still occur. LV features plug holes in the primary defense and prevent hits from being kills. LV provides a necessary second line of defense, and remains viable as threats evolve. The mix of aircraft survivability features is not 50:50. It depends on aircraft type and mission. Achieving the proper mix requires a candid assessment of each feature's measure of effectiveness, coupled with its cost, weight, and operational penalties. ■

About the Authors

Mr. Anthony Lizza is a graduate of the National Defense University's Industrial College of the Armed Forces, the University of Dayton and Purdue University Schools of Engineering. He has over 18 years experience in aircraft survivability and safety related research. He currently serves as tri-service Chairman of the JTCG/AS Vulnerability Reduction Subgroup. He has authored numerous technical publications and been an invited speaker for a variety of S/V related courses, symposiums, and conferences. He may be reached at lizzat@afrl.af.mil.

Mr. Czarnecki received his B.S. in Civil Engineering and his M.S. in Materials Engineering from the University of Dayton. He is a civilian with the AFRL Air Vehicles Directorate, Survivability & Safety Branch. Mr. Czarnecki specializes in Aircraft survivability, concentrating on impact physics of composites, projectile-induced hydrodynamic ram, and aircraft vulnerability reduction to the MANPADS shoulder-launched missile threat. He is a member of the JTCG/AS Vulnerability Reduction Subgroup and Chairman of that organization's Structures & Materials Committee. He may be reached at gregory.czarnecki@va.wpafb.af.mil

National MANPADS Workshop Addresses Three Key Topics

by Mr. Dave Hall, Mr. Tony Lizza, and Col. Steve Cameron
Articles Compiled by Mr. Dave Legg

The National MANPADS Workshop was held 15–17 December 1998 at the Sparkman Center, Redstone Arsenal, Alabama. The workshop brought together more than 100 experts for a technical exchange about how to make aircraft less vulnerable to Man Portable Air Defense System (MANPADS) threats. Three breakout sessions addressed vulnerability assessment methodologies, vulnerability reduction techniques, and vulnerability test facilities and capabilities. Dave Hall (NAWCWD), Tony Lizza (AFRL) and Col. Steve Cameron (OUSD [A&T]) respectively, chaired the sessions. The sessions used open and active dialogue to promote this technical interchange.

MANPADS Vulnerability Assessment Methodologies

Mr. Dave Hall

The MANPADS vulnerability assessment breakout session focused on two areas, one on target engagement dynamics and the other on target vulnerability to MANPADS given a hit. Both sessions included several briefings and followup discussion to answer the questions posed in the workshop handouts. A notional roadmap was developed for each of the two assessment areas.

Target Engagement Dynamics— The purpose of the engagement dynamics assessment session was to determine the capability to predict where MANPADS weapons are likely to hit the target, as a function of launch conditions, countermeasures employment, and aircraft maneuvers, given the environmental conditions at the time of launch. This assessment is critical to evaluating the effectiveness of vulnerability reduction features for MANPADS hits, because what is effective in one area of the aircraft may have little or no effect if the aircraft is hit elsewhere.

A-10 survives MANPADS hit and lives to fight again.

To determine hit point accuracy in modeling engagement dynamics, several issues need attention. Target signature models do not typically have the fidelity required to determine where the missile is likely to hit; very few targets have been modeled as an image, as opposed to a point source. In addition, target infrared (IR) signatures can vary considerably as a function of environmental parameters, making it difficult to predict where final impact of any given shot will occur.

Analyses comparing the output of all-digital fly-out simulations with actual flight test data have indicated that the terminal intercept velocities and angles predicted by the models are relatively accurate, but the miss distances and impact points on the target usually are not. The threat Signal Processor in the Loop (SPIL) is a promising technique for predicting hit location for these systems, and it should provide validation data to improve digital simulations. This technique has been shown to predict accurate hit locations for U.S. IR-guided missile systems.

Target Vulnerability to MANP ADS— Lack of sufficient historical MANPADS combat data is an impediment to determining exact MANPADS damage mechanisms. Combat data also are inconclusive in addressing the multi-engine versus single engine issue.

SURVIAC conducted a literature search to identify and evaluate previous MANPADS vulnerability assessments. All assessments were conducted manually, using drawings and threat templates. A standard approach to manual assessments is available, and the MANPADS project ongoing at SURVIAC is taking that approach to evaluate MANPADS threats to several aircraft.

However, MANPADS analysis techniques are only as good as the data available to support them. Inputs required for MANPADS vulnerability assessments include threat characterization data, damage data, and test data to support model verification and validation (V&V). Data for V&V activities include static and dynamic tests of actual aircraft structures and critical components. Dynamic shots are required to determine damage mechanisms from the kinetic energy in the missile and evaluate combined warhead and kinetic energy effects. The shortage of test data required to conduct vulnerability analyses is critical.

Unanswered to date is the question of how accurate the hit point prediction must be for vulnerability assessment. If the choice of vulnerability reduction technique depends on precisely where the missile hits, then experts probably need to improve the accuracy of engagement analyses, as well as consider other more robust vulnerability reduction techniques. A requirements analysis needs to be done to determine, for a number of aircraft types, how sensitive vulnerability reduction effects are to the assumed hit point. Those studies could also contribute to development of "rules of thumb" to estimate vulnerability reduction effectiveness.

Roadmap— Workshop participants proposed the following projects:

- Perform a hit location prediction accuracy requirements study, based on analysis of vulnerability sensitivity to variations in hit location and orientation, to determine what effect errors in hit location have on the assessed effectiveness of vulnerability reduction features.

- Use of the SPILs as they are developed to validate the digital MANPADS fly-out simulations for hit location prediction.

- Leverage ongoing activities under the Advanced Joint Effectiveness Model (AJEM) project. Some work in the vulnerability assessment methodology area is already partially funded, mostly as part of the AJEM-funded tasking. These efforts include improved penetration methodologies and component response modeling. Approximate milestones for interim capabilities are available for viewing in the *National MANPADS Workshop: A Vulnerability Perspective Proceedings*, Volume I, pages 538–39.

- Conduct dynamic and static tests and develop an improved test database to support generation of input data required for MANPADS vulnerability assessments. This work includes developing data on fuse functioning and missile debris characterization and effects.

MANPADS Vulnerability Reduction Techniques

Mr. Tony Lizza

The session began with several Government and industry briefings on classic HEI/API projectile and conceptual MANPADS vulnerability reduction (VR) techniques. The following group discussion explored what VR techniques had worked, what other potential VR techniques existed, and, finally, what should be done to reduce the vulnerability of current and future aircraft to this lethal threat.

The group discussion identified additional data sources that might be available to help address the MANPADS threat, known damage mechanisms and typical damage states caused by MANPADS threats, and the certain kill areas on current aircraft from the MANPADS threat.

The group then looked at what built-in vulnerability reduction techniques had prevented losses in combat. The principal example was extended nozzles like those on the F/A-18. In Desert Storm, at least four F/A-18s

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that were hit by MANPADS returned to base. Most returned to battle after engine replacement and relatively minor repair work. Generally, the group agreed that current VR techniques, although designed to HEI damage effects, had demonstrated some effectiveness against MANPADS threats. A majority argued that two engines would be better than one; however, the group also agreed that a single engine aircraft could survive a MANPADS hit if the hit point on the engine exhaust were well aft of any flight-critical subsystems. Other VR techniques believed to have potential were also identified.

The session identified the need for MANPADS threat performance characterization data; data on static and dynamic MANPADS test on actual aircraft; data on current vulnerability reduction technique performance against MANPADS; a low-cost, repeatable MANPADS test technique; and models that can assess MANPADS vulnerability reduction techniques. These were deemed essential to support vulnerability reduction technique development and evaluation.

Roadmap— Workshop participants proposed the following projects:

- Leverage ongoing activities under the F-16 Joint Live Fire (JLF) Program and other ongoing test programs

- Undertake a MANPADS JLF Program to assess in detail the vulnerability of current fleet aircraft

- Perform MANPADS Vulnerability Reduction, Phase I, testing to assess the effectiveness of vulnerability reduction techniques developed as a result of the MANPADS Characterization Testing, MANPADS JLF, and other related testing

- Perform MANPADS Vulnerability Reduction, Phase II, testing to refine techniques or develop additional techniques.

Vulnerability Test Facilities and Capabilities for MANPADS

Col. Steve Cameron

The purpose of this session was to assess the practicability and affordability of MANPADS testing by reviewing the current DoD test and evaluation capabilities for MANPADS vulnerability testing. The group began by summarizing the desired test conditions in terms of engagement geometry, target realism, and data expected to be required by the methodology group.

Every F/A-18 that was hit by a MANPADS survived and was returned to combat in short order .

For realistic lethality, the group agreed that the MANPADS missile would require a live warhead, natural fuzing, and a realistic missile/motor body. A realistic target would involve target orientation for normal forces (right side up), application of flight loads, airflow, tactical loading of fuel and munitions, pressurization of the aircraft (most important for cargo aircraft), and, finally, a running aircraft.

Taking these considerations into account, the group determined that the most important items in conducting MANPADS vulnerability testing were geometry, velocity, blast location, warhead function, and test asset recovery. The group noted that the last factor explained why actual live firings of missiles at flying aircraft, although important demonstrations, were not the optimum method for vulnerability testing. Control of shot lines and recovery of the test asset were paramount, participants emphasized, for gathering the data necessary to construct vulnerability models.

The group placed aircraft configuration at the next level of importance, with pressurization being more important for civil aircraft and munitions loading more important for military aircraft. Of lesser importance were air flow, especially for slow-flying aircraft such as helicopters, g-loading, and the choice of a missile that was the actual threat or a surrogate.

One surprise occurred in discussion of data collection requirements. Participants noted the need for the standard information required for vulnerability model design and verification. In addition, a member of the law enforcement community pointed out that information gathered from test sites could aid in the forensic efforts to investigate future terrorist uses of MANPADS. Not only might this information help locate the perpetrator; it might also allow determination of the exact missile used, leading to use of the data to validate vulnerability models.

The group concluded that DoD facilities had substantial capability to conduct MANPADS testing, and only relatively minor investment, depending on the methodology required, might be needed to increase capability.

Roadmap— Workshop participants proposed the following projects:

- Some sled track durability enhancements might be required if a large number of shots is necessary and facilities might require modification if more than just sections of large aircraft must be used.
- Also, if the magnetic induction gun at China Lake is used instead of a sled track, gun modification would be required to impart fewer g's to the threat missile.
- Development and procurement of surrogate missiles would be required if a large number of shots is required, and airflow facilities would require some upgrades for fast-moving targets.

In summary, the breakout sessions accomplished the chief objective of the National MANPADS Workshop by promoting the open and active technical dialogue necessary to develop cost-effective vulnerability reduction techniques for the MANPADS threat. ■

About the Authors

Mr. Hall has 30 years experience in missile ordnance system design analysis, weapons systems requirements definition, mission effectiveness analysis, survivability analysis, technical contract monitoring and model and simulation verification, validation and accreditation (VV&A). Dave is currently Chief Analyst and Head of the Analysis Branch of the NAWCWD Survivability Division; Co-Director of the Joint Accreditation Support Activity (JASA); Chairman of the Methodology Subgroup in the JTCG/AS; and Chairman of the NAWCWD Science and Technology Network for Analysis Resources. He may be reached at halldh@navair.navy.mil.

Mr. Anthony Lizza is a graduate of the National Defense University's Industrial College of the Armed Forces, the University of Dayton and Purdue University Schools of Engineering. He has over 18 years experience in aircraft survivability and safety related research. He currently serves as tri-service Chairman of the JTCG/AS Vulnerability Reduction Subgroup. He has authored numerous technical publications and been an invited speaker for a variety of survivability/vulnerability related courses, symposiums, and conferences. He may be reached at lizzat@afrl.af.mil.

Col Cameron has served as an experimental test pilot on several programs, most notably the B-2 bomber program, and various staff positions during two previous tours at the Pentagon. As the Principal Assistant for Systems Assessment, OUSD(A&T) he provided financial and technical oversight of the JTCG/AS and ME, developmental test oversight of the 207 major programs on the OSD Test and Evaluation Oversight list, and oversight of the Joint Test and Evaluation Program. He may be reached at camerose@acq.osd.mil. ***Editor's Note:*** *Col Cameron has been re-assigned to the Air Force Test Pilot School at Edwards AFB, CA. OUSD(A&T)DTSE&E/SA was disestablished on 7 June 99.*

Mr. Legg has 16 years of experience in aircraft survivability requirements definition and mission effectiveness analysis. He is currently a Senior Engineer with the SURVICE Engineering Company supporting ground and air system survivability evaluations. Dave is also a member of the AIAA Survivability Technical Committee. He may be reached at dave@survice.com

MANPADS Survivability
Depends on Aircraft Design and Type

by Mr. Jamie Childress, Mr. Robert Tomaine and Mr. Michael Meyers

Ability to survive attack by the MANPADS varies greatly, depending on the type of aircraft and its design features. Here, three authors—Jamie Childress, Robert Tomaine, and Michael Meyers—examine the MANPADS survivability of large transports, rotorcraft, and fighters, respectively.

Large Transport Survivability Against the MANPADS Threat

Mr. Jamie Childress
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"For the aircrews of large military transport aircraft, the thought of being shot down by a shoulder-fired, heat-seeking missile while flying at low altitude is probably their worst nightmare."
Armed Forces Journal International, October 1996

Transports have been the targets of MANPADS missile attacks in the past, and many of those encounters resulted in the loss of the aircraft. Of the thirty-four confirmed attacks by MANPADS on civilian transports between 1975 and 1998, twenty-four resulted in the loss of the aircraft and its passengers.[1] This is in contrast to four MANPADS hits on F/A-18s in the Gulf War, without the loss of a single aircraft.[2] If we were to use only this data to derive the MANPADS Probability of Kill given a Hit ($P_{K/H}$) of both transports and modern twin engine fighter aircraft, we would conclude that unprotected transports had a $P_{K/H}$ of 0.7 and twin engine fighters a $P_{K/H}$ of zero. This example shows that transport aircraft are more vulnerable to MANPADS hits than twin engine fighters.

The military needs to consider the survivability of all transport aircraft, even those not intended for frontline combat. The following list identifies some of the issues inherent in MANPADS survivability of transport aircraft.

Figure 1. The C-130 Hercules is the prime transport for paradropping troops and equipment into hostile areas. (Photo by Tech. Sgt. Howard Blair.)

Transport Signature Makes Them an Easy Target

- **Engines–** Transports have large engines, which provide a correspondingly large thermal signature to IR MANPADS seekers operating in both the 3 to 5 micron and 8 to 12 micron IR bands. The thermal signature of transports is generally more than sufficient to allow targeting of the aircraft well beyond the kinematic range of the missile.
- **Navigation Lights–** Navigation lights are excellent IR emitters and can prove very attractive to MANPADS from certain angles.
- **Local Hot Spots–** Transports may have air conditioning or auxiliary power units that operate for the duration of the flight, creating additional IR signature sources.
- **Visual Signature–** The large size of transports makes them much easier to acquire visually than small fighter jets. This large visual signature allows transports to be tracked and targeted beyond the maximum range of most MANPADS.

Tactical Employment of Transports Makes Avoiding MANPADS Difficult

- **Speed and Maneuvering–** The limited maneuvering capability and subsonic speed of transport aircraft provide a very simple firing solution and a high probability of intercept for most MANPADS engagements.

- **Airport Operations–** The time of greatest risk from a MANPADS attack is during departure or arrival at an airport. The transport is low, slow, and may be flying on a known schedule. A number of terrorist and rebel MANPADS attacks on transports have been launched from uncontrolled civilian areas around airports.

Transport Structures Ha ve Limited Redundancy

- **Wings–** Transport wings are generally two spar wings and are not capable of sustaining flight after the loss of a spar. A MANPADS impact near a spar could cause severe damage from direct blast or hydrodynamic ram pressures.
- **Fuselage–** Many transports are pressurized. Testing has shown that even the relatively small warhead of a MANPADS can cause catastrophic damage to a pressurized hull, resulting in the complete rupture of the fuselage. Fortunately, this effect is greatly reduced at lower altitudes where MANPADS encounters are most probable.

Systems Separation and Fire Suppression are Key to Transport Survivability

- **Engine Redundancy and Separation–** Multiple engines with wide separation make the loss of all aircraft propulsion an unlikely event from a single MANPADS hit. However, this positive survivability feature has limited value if an uncontrolled fire or catastrophic structural/system damage ensues from an engine hit.
- **Flight Control R edundancy–** Multiple hydraulic systems and flight controls provide improved survivability. However, many non-frontline transports do not have sufficient hydraulic system separation to prevent catastrophic flight control loss if a critical area is hit.
- **Fire and Explosion Suppression–** The two primary kill mechanisms of a MANPADS hit on transports are ullage explosion and fire. Most transports have very limited fire suppression systems. A sustained fire would ultimately result in either loss of critical systems or structural failure. Non-frontline transports do not have ullage inerting systems. An ullage explosion initiated by a fragment or high explosive blast would most likely result in an instantaneous structural kill of the aircraft.

Countermeasures on Transports are Limited or Non-Existent

- **Warning Systems–** Few transports carry missile launch warning detectors. MANPADS missile launches are difficult to detect from the air, especially from the target aircraft. In the Gulf War, only about 10 percent of the combat pilots hit by MANPADS were aware that they were under attack or that a missile had been launched.
- **IR Counter Measures (IRCM)–** Flares and other active IRCM systems are only carried on frontline transports or high value aircraft. When IRCM is available, it is often used proactively, by dispensing flares in a preset schedule during landing or takeoff.

Transports have not traditionally received the attention to vulnerability hardening compared to tactical aircraft. Hardening transport aircraft against MANPADS attacks is no simple task and must be weighed against the aircraft mission, cost, and weight implications of more survivable systems. However, the proliferation of these lethal weapons to all corners of the world necessitates that we recognize military transport vulnerabilities. Warfare is changing from the entrenched battlefields of our past, to the remote and vague battle-lines of future conflicts. If we can't protect our transports we may never get to the war.

Endnotes

1. Crosthwaite, Kevin, "Combat History" in *National MANPADS Workshop: A Vulnerability Perspective Proceedings, Vol. I*, December 15–17, 1999, Redstone Arsenal, Huntsville, AL.

2. Meyers, Michael, "Fighter MANPADS Issues" in *National MANPADS Workshop: A Vulnerability Perspective Proceedings, Vol. II*, December 15–17, 1999, Redstone Arsenal, Huntsville, AL.

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Rotorcraft Survivability Against the MANPADS Threat

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U.S. Army Aviation doctrine calls for Nap-of-the-Earth (NOE) operation for all helicopter assets. In addition, Army Aviation missions of close troop support, armed reconnaissance and attack of ground forces and ground vehicles are therefore normally conducted near or within hostile territory. Therefore Army helicopters have a high probability of encountering MANPADS threats. Design philosophy for helicopter survival in this environment is to avoid detection and engagement by providing susceptibility reduction, and ballistic tolerance consistent with the primary threat and considering weight constraints similar to any aircraft, and as a last resort provide crew survival with crashworthiness even if the aircraft does not survive. The Army's next generation helicopter, the RAH-66 Comanche utilizes this design philosophy with an unparalleled emphasis on susceptibility reduction. This includes significant signature reduction in RF, IR, acoustics and visual signatures. Combined with an advanced technology target acquisition system and much improved situational awareness, the signature reduction provides standoff capability that generally allows engagement of threats before Comanche can be detected.

Ballistic tolerance for Army helicopters is directed primarily at the high density individual small arms and threat vehicles with armament ranging from 7.62mm up to 30mm. Individual crew protection, parasitic armor for crew and flight critical components, fuel inerting systems, fire detection and suppressant systems, design redundancies and structural sizing to withstand ballistic hits are common means of providing ballistic tolerance for these vehicles. Triple redundant fly by wire flight control system, physically separated twin engines, run-dry drive systems, and ballistically tolerant main rotor actuators are examples of the ballistic tolerance design for the Comanche. These systems are examined and tested against specific threat caliber weapons. Analysis and testing against MANPADS warheads is seldom performed. It is logical to assume that these measures will provide at least limited protection against MANPADS hits. Historically, analysis and war gaming exercises seldom attempt to account for this protection. In terms of analysis, modeling and design for survivability of modern Army helicopters against MANPADS threats, several questions remain. How effective are classical ballistic vulnerability reduction techniques against MANPADS warheads? Given strict weight and cost constraints, are there feasible additional/unique vulnerability features? Do potential vulnerability reduction approaches provide equal/greater survivability than susceptability reduction features employed in today's designs?

Boeing-Sikorsky RAH-66 Comanche Ar med Reconnaissance Helicopter

Tactical Aircraft Survivability Against the MANPADS Threat

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F/A-18 experience in Desert Storm provides valuable information for assessing fighter aircraft vulnerability to MANPADS. Additional information is available from F/A-18 joint live fire (JLF) tests conducted about 1990 at China Lake, California. Combining these data provides insight into the vulnerability of fighter aircraft and helps identify potential vulnerability reduction concepts.

In Desert Storm, four Marine F/A-18s were hit by MANPADs, and all returned to base safely. All impacts were in the engine bay, on or near the "turkey feathers" of the exhaust section. One aircraft with severe damage to both engines' exhaust sections was able to fly 125 miles to a recovery base. Two of the aircraft lost one engine, demonstrating the survivability of a twin-engine design. By contrast, four single-engine AV-8B aircraft were hit, and all four were lost .

The F/A-18 JLF tests of statically detonated MANPADS warheads showed that aircraft subsystems were the most vulnerable components. Since then, F/A-18 subsystems have been designed to meet vulnerability requirements for countering high explosive incendiary threats. The design separates fuel tanks, flight controls, and hydraulics from the engine bays. Engine design features can also improve survivability against MANPADS.

This F/A-18 Hornet was damaged by a SAM in the Persian Gulf.

Exhaust nozzle fuel lines can be shut off by using leak detection systems that minimize the fuel feeding a fire. This system is being employed in the F/A-18E/F design.

Countermeasures that bias MANPADS impacts to a vertical tail or outer wing can greatly improve the survivability of single- or twin-engine fighter aircraft. A review of F/A-18 midair incidents showed that one of the two vertical tails or a complete outer wing could be severed without affecting get-home and landing capability.

Analysis of Desert Storm incidents and JLF tests shows that the F/A-18 twin-engine design is highly survivable against the MANPADS threat. Single-engine aircraft may also be able to survive, given a hit, but to a lesser extent. ■

About the Authors

Mr. Childress received his B.S. in Aerospace Engineering from University of Colorado, Boulder. The Boeing programs he has supported include the A-6, F/A-18, AV-8B, and V-22. In addition he has also supported programs with the ATF, F-22, JSF, A-X, Decoupled Fuel Cells, Composite Affordability Initiative, IR&D, Muzzle Blast, Advanced Composite Armor, Nitrogen Inflated Ballistic Bladder, z-pinned skin fusing, and various classified programs. He may be reached at James.Childress@PSS. Boeing.com.

Mr. Tomaine received his B.S. in Aerospace Engineering from Virginia Polytechnic Institute & State University and his M.S. in Mechanical Engineering from George Washington University. He is currently Chief of the Air Vehicle Branch in the Comanche Program Managers Office, PEO Aviation, with technical and programmatic responsibility for the design and development of the Comanche airframe, rotor systems, flight control system, environmental control system, and all airframe subsystems. He also has system responsibility for survivability including low observables, handling qualities, weight, flight performance and system safety. He may be reached at tomainer@comanche.redstone.army.mil.

Mr. Meyers has been a Boeing Company employee for 37 years. He is currently leading the F/A-18E/F vulnerability team. He is responsible for the program vulnerability assessments, trade studies and live fire testing plans and reporting. Previous areas of responsibility included vulnerability and survivability evaluations on the A-12, F-15, F/A-18A/B as well as advanced design configurations. Mr. Meyers is a member of the Advisory Committee for the Aircraft Vulnerability to MANPADS Study and is a Senior Advisor for the AD HOC Committee on Aircraft Vulnerability. He may be reached at michael.meyers@boeing.com.

Defense Acquisition Deskbook and Aerospace Systems Survivability

by Mr. Hugh Drake and Mr. Dave Hall

In fiscal year 1999, the JTCG/AS initiated a task updating the survivability sections of the DoD Acquisition Deskbook (DAD) to address the needs of the Tri-Services and industry's survivability community. The existing survivability sections of the DAD are based on MIL-STD-2069, which has not been updated in 16 years.

A new approach was established that will provide: 1) an update to the DAD, 2) an Aerospace Systems Survivability handbook series, and 3) the second edition of Distinguished Professor Ball's Survivability Textbook (in progress). These products will overlap somewhat, but they basically address the needs of different customers.

There has been some activity within the services in the recent past on survivability standards and handbooks. When acquisition reform removed most military standards from the inventory, there were no survivability industry standards for the DoD to fall back on, as there are in other functional areas.

The Survivability Textbook

In examining the relationship between the DAD, the handbook series and the textbook, along with the role each would play in addressing survivability, it was determined that three elements should be covered:

- Intellectual construct
- Examples of design practices
- Survivability and the DoD acquisition process

The handbook, in conjunction with a modification to the deskbook, will address the third element, walking the user through the bureaucratic maze to develop an effective survivability program. The textbook addresses the first two elements, the intellectual construct and examples of design practices.

Chapter 1 of the revision of the Survivability Textbook is almost completed and is available for review on the Web (www.aircraft-survivability.com). The entire 800-page second edition will be issued both as a compact disk and in hard copy [published by the American Institute of Aeronautics and Astronautics (AIAA)]. The intent is to "hot reference" sections of Chapter 1 in the Defense Acquisition Deskbook. The full second edition of the textbook is planned for completion by the end of 2000.

The Defense Acquisition Deskbook Survivability Section

The deskbook addresses what to do in a survivability program, the handbook series addresses how to do it, and the textbook addresses the entire survivability discipline. The pertinent parts of the Defense Acquisition Deskbook will provide hotlinks to the Aerospace Systems Survivability Handbook Series and the Survivability Textbook. These documents will be used by defense acquisition programs that need to develop survivability program plans for the centers, laboratories, and contractors responsible for aerospace systems survivability project management, engineering, analysis, and test and evaluation. We will work with the Acquisition Deskbook Joint Program Office (JPO) to determine whether placing the handbook series both in the deskbook's library and on the JTCG/AS Web site (http://jtcg.jcte.jcs.mil:9101/) is an effective way to proceed.

The Handbook Series

The Aerospace Systems Survivability Handbook series is designed to document the elements of the survivability process, how they relate to other defense acquisition activities, and how the associated survivability activities are accomplished. It is being organized from a pre-acquisition and program management perspective. A work breakdown structure (WBS) format will be used for each technical volume in the series.

All activities and functions performed in aerospace systems acquisition, including survivability, fall into one of four major categories

1. Management
2. Engineering
3. Test and evaluation
4. Systems analysis.

The handbook series will correlate the survivability process and its activities and functions with all elements of defense acquisition.

Plans

FY99—A version of the deskbook and handbook will be drafted for community review by 30 October 1999. This draft will have holes, but it will integrate relevant portions of various existing materials, plus some new material, into the WBS table of contents for the deskbook. It will also have references to sections of Chapter 1 of Dr. Ball's textbook. This will be a standalone version of the deskbook survivability section (2.6.6) for review.

FY00—Pertinent parts of the DAD will be updated with hotlinks to the Aerospace Survivability Handbook series and the Survivability Textbook. The Handbook Series will thoroughly document current survivability project engineering, analysis, and test processes and procedures in a how to format and correlated with related acquisition processes and procedures. ■

About the Authors

Mr. Drake received his B.S. in Mathematics from California State Polytechnic College (Cal Poly) in 1961. He is one of the recognized Pioneers of Survivability and is credited with playing a major role in the establishment of the JTCG/AS and the Survivability Division at NAWCWPNS China Lake, CA. He retired from the NAWCWPNS in 1988 and is presently Vice President of ASI Systems International, a wholly owned subsidiary of SRS Technologies. He may be reached at 760.375.1442.

Mr. Hall currently serves as Chief Analyst and Head of the Analysis Branch of the NAWCWD Survivability Division; Co-Director of the Joint Accreditation Support Activity (JASA); Chairman of the Methodology Subgroup in the JTCG/AS; and Chairman of the NAWCWD Science and Technology Network for Analysis Resources. He may be reached at halldh@navair.navy.mil.

MANPADS Combat History

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and paced for survivability. In this phase, Desert Storm pilots operated at higher altitudes and at night to protect aircraft from MANPADS. As the ground war grew closer, the Allied forces began to "prep" the battlefield. Pilots were ordered to fly as low as necessary, increasing the risk. Finally, when the

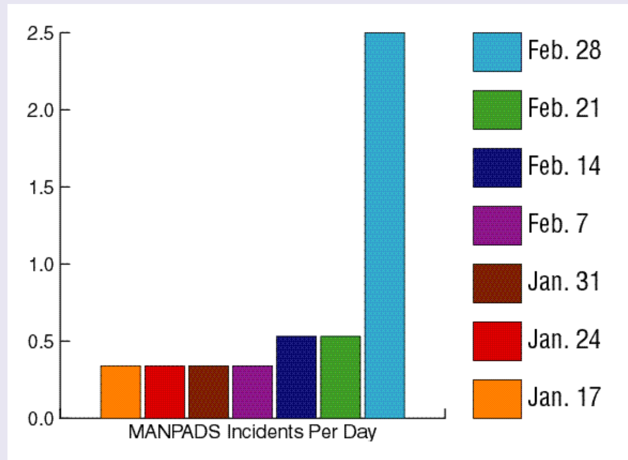

Figure 3. Operational Necessity's Effect on MANPADS Incidents in Desert Storm

ground war started, close air support of friendly troops was imperative. Figure 3 shows the frequency of MANPADS engagements throughout Desert Storm.

MANPADS were not a significant threat early in the war, with an average of one damage incident every 3 days. This frequency increased to one every other day while the battlefield was being prepared. During the ground war, MANPADS incidents jumped to an average of 2.5 per day.

Fortunately, Desert Storm saw so few combat incidents that no one type of aircraft received a statistically significant number of hits. Although this lack of data makes it difficult to calculate the relative survivability of aircraft types, some observations can be drawn from the success of the F/A-18 aircraft. Four F/A-18s were damaged by MANPADS, and all four landed safely, were repaired, and returned to combat. The extended rear tail feathers on the F/A-18 appear to move MAN-

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Pioneers of Survivability

James "Jim" Foulk

by Mr. Jeffrey Foulk

One of several unheralded pioneers of aircraft survivability is James Foulk. Jim is known today as president of the SURVICE Engineering Company, which he founded 18 years ago to provide analysis support to the survivability/vulnerability community. Along the path that led to SURVICE, however, he contributed significantly to aircraft survivability evaluation, testing and design. Most notable was his influence and leadership in developing the UH-60A Black Hawk, still considered one of the more survivable helicopters in the fleet today.

Jim graduated from the University of Delaware in 1959 with a B.S. in Mechanical Engineering. After graduating, he moved to Ohio and went to work for the Standard Oil Company, specializing in development and experimental evaluation of fuels and lubricants for automotive applications. In 1962 he took a job as an automotive engineer for the U.S. Army Materiel Test Directorate at the Aberdeen Proving Ground, MD. There he conducted experimental tests of surface vehicles under laboratory and field conditions, acquiring experience in propulsion, drive systems, and application of fuels and lubricants.

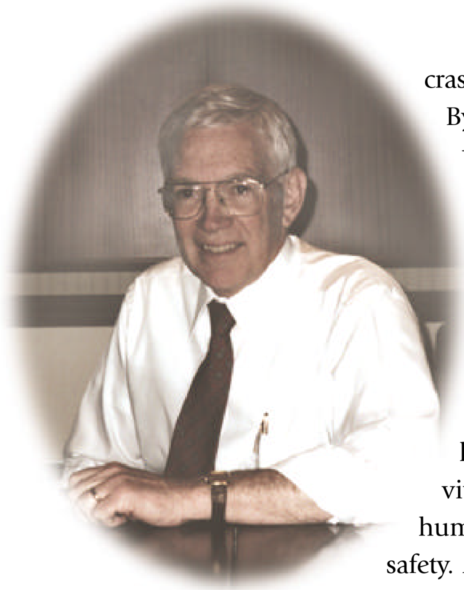
In 1963, one might say, Jim's career in aircraft survivability began to take flight. During that year he accepted a position with the U.S. Army Ballistic Research Laboratories (BRL), known today as the Army Research Laboratory (ARL). He spent the next 12 years immersed in numerous aircraft vulnerability projects with what is now the Experimental Design, Conduct & Analysis Branch of the Ballistics & NBC Division.

Early in this period, Jim and a small group of coworkers collected and carefully studied the increasing volume of aircraft combat damage reported from Southeast Asia and urgently set about finding practical solutions for the current Army fleet. Jim turned the BRL range facilities into a dedicated proving ground for actual gunfire experiments with operating helicopters and components under scientifically controlled conditions. Existing subsystem flaws were demonstrated and diagnosed, and candidate solutions were subjected to trial. The results, combined with threat-specific interpretations, formed a compelling case for practical, flight-weight vulnerability reduction (VR) in aircraft, using armor only as a last resort.

Jim and his group, in collaboration with other Army safety/survivability activities, organized a relentless, successful effort to lobby the Army aviation specification writers and decision makers. At the same time, these pioneers went to great lengths to show their results to industry developers, traveling to their facilities to educate their designers. Several unprecedented developments occurred: current fleet aircraft began to receive VR modifications, the industry assigned employees to VR issues, VR emerged as a recognized discipline and became a weighted evaluation factor in new aircraft competitive programs, and military and industry VR specialists joined together into what is now a permanent, cooperative mode of operations.

Many innovative ideas resulted from Jim's 12 years of aircraft vulnerability efforts working with other BRL survivability pioneers, such as Don Mowrer, Walt Vikestad, Walt Thompson, and Branch Chief, Roland Bernier. One keypoint was the need for a vulnerability information center that could sustain and expand on the good work that group accomplished in educating and helping industry to reduce aircraft vulnerability. This idea eventually became Jim's vision for a Survivability/Vulnerability Information Analysis Center.

In 1974 Jim moved to Stratford, CT, where he joined the Sikorsky Aircraft Division, United Technologies Corporation, as head of the Safety and Survivability Program. In this position, he planned, directed, and coordinated research on and development of system safety, detectability, threat avoidance, vulnerability, and



crashworthiness technology. By 1976 he was promoted to System Engineering Manager, responsible for all UH-60 helicopter system engineering activities—reliability, maintainability, weight control, aerodynamics, dynamics, acoustics, handling qualities, survivability/ vulnerability, human factors, and system safety. At Sikorsky, Jim's leadership and innovative design approaches helped ensure that substantial vulnerability reductions and improved safety features were integrated into the UH-60A Black Hawk helicopter.

In 1978 Jim moved to an aircraft survivability start up group at Science Applications, Inc., (SAI) in Albuquerque, New Mexico. At SAI he set out to build a vulnerability business. After serious marketing and constant travel, he recruited his former BRL boss, Roland Bernier, and his own wife Nancy and established a small vulnerability office in Bel Air, Maryland. During this time, he performed various vulnerability studies for the Army, antiship missile high energy laser weapon vulnerability studies for the Navy, combat damage analyses for the Air Force, and a vulnerability study for Agusta, resulting in innovative VR design solutions for the A129 attack helicopter. After 3 years at SAI, he decided to pursue the dream of his own vulnerability business.

In 1981 Jim and Nancy acquired the SAI office assets, moved everything to their house, and started the SURVICE Engineering Company. The name resulted from Jim's continued vision of a Survivability/Vulnerability Information Analysis Center (IAC), hence the "service with a U in it." Jim's vision persisted and with much work and coordination on the part of Jim, even at the expense of his new business, SURVIAC was established, and awarded in 1984 to the team of Booz·Allen & Hamilton and SURVICE. In the years that followed, Jim's dedication and hard work in the field of aircraft survivability helped establish both a very successful IAC and a survivability business at SURVICE.

Jim is most proud of bringing talented vulnerability experts together with bright young engineers and analysts to allow them to grow and mature in the vulnerability field. As a result, SURVICE now offers one of the most experienced group of aircraft survivability/vulnerability engineers and analysts found anywhere.

Throughout his career Jim has been a "behind the scenes" person, participating in a number of professional societies, national coordinating groups, joint working groups, and other organizations. He was one of the founding members of the National Defense Industrial Association (NDIA) Combat Survivability Division. His work on the UH-60A Black Hawk was instrumental in Sikorsky's earning the American Helicopter Society's Grover E. Bell Award for outstanding contributions to helicopter development. Without question, however, Jim's most important reward is knowing that lives and aircraft may be saved as a result of his efforts to enhance aircraft survivability.

Jim and Nancy, married for 40 years, have raised three children—Jeff, David, and Cindy. When not working, as occasionally happens, they spend time playing golf, talking about business, and fixing up their home. The recent addition of three grandchildren has also given them the opportunity to babysit occasionally.

During this period, Jim was responsible for analytical and experimental studies in ballistic survivability of aircraft and related studies for application to surface vehicles. He led efforts to develop design criteria to increase survivability of aircraft systems, including engine, drive, rotor, control, fuel, hydraulic, electrical, structural, and crew station. He was also responsible for developing new and improved analytical methodology for determining and predicting aircraft survivability.

Many of the military aircraft seen operating today, new or modernized, are endowed with at least a few tangible products with Jim and his coworkers' imprimatur. Some rely on literally dozens of such VR measures to achieve the battle toughness for which they are touted. ■

Editor's Note: Jim and Jeff are father and son, respectively. Jeff is employed by SURVICE Engineering.

Joint Live Fire Program Tests Full-Up Stinger Missile Against F-14 Tomcat

by Mr. Thomas Julian

The Director, Operational Test and Evaluation (DOT&E)-sponsored Joint Live Fire (JLF) Program performed a live fire test shot of a Stinger missile against a recently retired F-14 Tomcat on Wednesday, July 14, 1999. The test was the first in a series of tests with complete aircraft to assess the vulnerability of our aircraft to shoulder-fired, man-portable missiles. The test was conducted by the Navy's Weapons Survivability Laboratory, at the Naval Air Warfare Center, China Lake. The missile was shoulder-launched by Marine Corps personnel, flew free flight, guided itself to the target, and detonated on impact with the aft portion of a static F-14 aircraft. Analysts, who are developing modeling and simulation capabilities for prediction and assessment of aircraft vulnerabilities to Man-Portable Air Defense Systems (MANPADS), are evaluating the damage to the test article. Representatives from DOT&E, the services, and industry witnessed the test first-hand.

INCOMING! Stinger missile fired by US Marines of the Third Low Altitude Air Defense Battalion (Camp Pendleton, CA) homes in an F-14 Tomcat in a Joint Live Fire test at the Naval Air Warfare Center Weapons Division, China Lake, CA.

This test demonstrated that, by working as a team, we have the ability to accomplish several different objectives with one test. The U.S. Marine Corps' Third Low Altitude Air Defense Battalion, from Camp Pendleton, provided the fire team and basic Stinger missile. For them, this test was a realistic training exercise—an example of one of the SECDEF themes, namely combining testing and training opportunities. It also served to develop test techniques for JLF, provided realistic lethality data for the Stinger Program Office, and realistic data for aircraft vulnerability assessment and future vulnerability reduction efforts.

The China Lake MANPADS program is just one of several closely coordinated activities currently underway in DoD to examine the MANPADS issue. The JTCG/AS, JLF, and the Services are sponsoring efforts in the area, and working as a team to quantify the threat, and develop susceptibility and vulnerability reduction approaches. Examples of this work include a JTCG/AS MANPADS study (see Editor's Notes on page 3 and "Aircraft Vulnerability to MANPADS Weapons" on page 4), an Air Force Research Laboratory (AFRL) evaluation of the lethality of several threat weapons against US systems (with testing at the Army's Aberdeen Proving Ground), and JLF's evaluation of the F-16 vulnerabilities, which is managed at AFRL with testing at Eglin AFB's Chicken Little Joint Program Office. By working as a team, the data, resources, and lessons learned are shared by all the services.

In addition to evaluations of aircraft and threat interactions, work is underway to assess the best way to assure realism in an investigation, yet retain the ability to collect pertinent threat and damage data. China Lake's Weapons Survivability Laboratory (WSL) has been conducting free-flight autonomous guidance and detonation of actual weapons against complete aircraft. The WSL also developed and operates, as part of the DOT&E/LFT funded JLF Program, the MIKES gun—the Missile Intercept Kinetic Energy Simulator. MIKES is a gas gun, capable of launching an entire missile, or just the warhead, at realistic velocities and close ranges. This test technique is being developed to obtain impacts under controlled conditions described in terms of impact location, angle, and velocity. It also allows a stationary target aircraft to be operating at combat power, while positioned in an airflow environment from China Lake's High-Velocity Airflow System (HIVAS).

An Air Force MANPADS investigation, also sponsored by JLF, involves launching a MANPADS missile down a sled track to evaluate (and develop the potential to reduce) threat effects on single engine aircraft. The F-16 is being used for this evaluation, with targets salvaged from crashed systems or retired aircraft from Davis Monthan AFB. AFRL's Survivability and Safety Branch at Wright Patterson is managing the program, with testing performed at a track facility operated by the 46th Test Wing's Chicken Little Program Office at Eglin AFB. Several shots have been successfully launched against F-16 wings. This MANPADS rail launch method has, however, highlighted a fuzing problem that must be solved prior to rail launches against complete F-16's. In free flight testing, the Chicken Little Office recently launched a Stinger missile at an F-16 wing (another effort combining Stinger Program Office objectives with those of the aircraft survivability enhancement community).

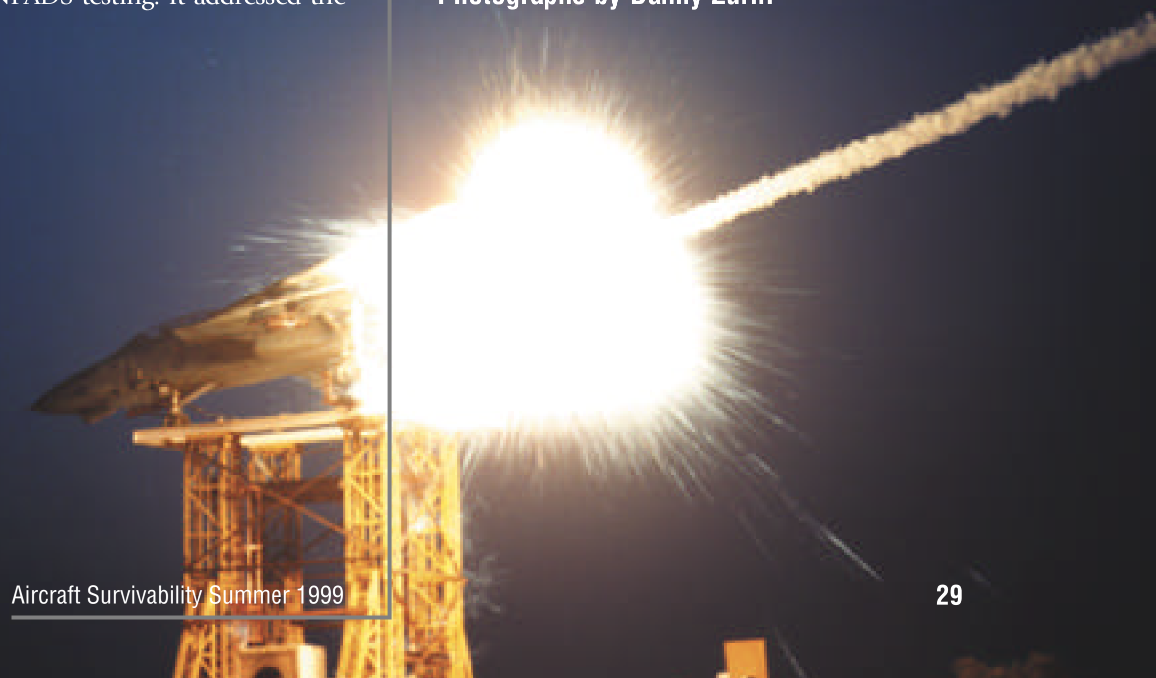
The Aberdeen Test Center (ATC), located at Aberdeen Proving Ground, also has a capability for conducting sled track tests. The ATC recently adapted its track to launch MANPADS against aircraft. As part of AFRL's Air Defense Lethality Program, ATC is currently perfecting its methodology for conducting launches of MANPADS missiles against transport and other large aircraft.

The Institute for Defense Analyses (IDA) recently completed a study, sponsored by DOT&E/LFT, to assess the best way to conduct MANPADS testing. It addressed the question: "What is the best launch method to use in order to collect realistic MANPADS vulnerability data." The study takes into account cost, realism, target fidelity, attack angles, payload weight, etc. Early indications are that the "best" way may well be a combination of different approaches, depending on the program's objectives, budget, and required realism.

A number of DoD elements are working together to assure our ongoing programs are complementary, sharing resources and data, to assess this threat to our aircraft, and come up with ways to counter it. ■

About the Author

Mr. Julian is a staff action officer in the Live Fire Testing office of the Office of the Secretary of Defense, working for the Deputy Director, Operational Test and Evaluation, Live Fire Testing, Mr. Jim O'Bryon. Most his 20 year career has been spent working on Live Fire Programs. The last 7 years he has worked in the OSD Live Fire office at the Pentagon. He was previously with Chicken Little Project Office at Eglin AFB and also Aberdeen Proving Ground working on vulnerability programs for the Army. He is primarily a Land Combat Systems expert, but has expanded his area of knowledge into both fixed and rotary wing aircraft. He may be reached at TJulian@dote.osd.mil.



DIRECT HIT! Stinger missile warhead detonates after striking the F-14. The smoke ring came from the warhead detonation. Photographs by Danny Zurn.

Combat Survivability Annual Awards

by Mr. Dale Atkinson
NDIA Combat Survivability Division
Executive Board Member

The National Defense Industrial Association's (NDIA) Combat Survivability Division recognizes superior achievement in the combat survivability field through two annual awards. The NDIA is soliciting nominations for these awards, which will be presented at the NDIA "Aircraft Survivability 1999: Challenges for the New Millennium" Symposium at the Naval Postgraduate School, Monterey, California, on November 16-18, 1999.

The awards cover the entire spectrum of survivability, including susceptibility reduction, vulnerability reduction, and related modeling and simulation. The Combat Survivability Division Awards Committee screens candidates and recommends honorees to the Executive Board for final approval. The criteria for the awards are shown below.

Survivability Leadership Award. This award is presented to an individual who has made major contributions to enhancing combat survivability. The individual selected must have demonstrated outstanding leadership in furthering combat survivability overall or have played a significant role in a major aspect of survivability design, program management, research and development, modeling and simulation, test and evaluation, education, or the development of standards. This award is based on demonstrated leadership of a continuing nature.

Survivability Technical Award. This award is presented to an individual who has made a significant technical contribution to any aspect of survivability. The award will be presented for either a specific act or contribution, or for exceptional technical performance over a prolonged period. Individuals at any level of experience are eligible for this award.

Submission of Award Nominations— Award nomination may be submitted by fax, mail, or via the Award Nomination Web page, located at http://www.ndia.org/events/brochure/094/094.htm. Submit nominations by mail to Charles Wilkins, NDIA Event #094, 2111 Wilson Blvd., Suite 400, Arlington, VA 22201-3061, via the internet at the address above, via fax to 703.522.1885 or via E-mail to cwilkins@ndia.org.

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PADS impacts away from flight-critical components. As a vulnerability reduction technique, this design holds promise.

Implications

Combat history demonstrates that aircraft will be hit by MANPADS, in spite of such vulnerability reduction tactics as flying high, flying at night, and using countermeasures. Operational necessity usually forces pilots lower and into daylight as a conflict progresses. Aircraft performing critical missions during the Desert Storm ground war, for instance, suffered the most from MANPADS attacks.

Although MANPADS are lethal, a hit does not equal a kill. Some aircraft survive MANPADS hits; some, like the F/A-18, have survived very well. F/A-18s use features designed originally to improve their survivability against non-MANPADS threats, but these basic survivability features have also helped against MANPADS. A close examination of these vulnerability reduction features should reveal the techniques that will best limit MANPADS damage.

History also shows that MANPADS teams have traditionally operated during daylight. As night vision devices become more readily available, MANPADS teams will no doubt use them. U.S. Forces' recent demonstrated preference for night operations will surely compel opponents to improve their night operations. If these teams can operate effectively day and night, MANPADS could become even more effective against U.S. operations.

Finally, history shows that MANPADS can track, intercept, and bring down civil aircraft. This capability could presage a much wider MANPADS threat if these weapons fall into the wrong hands. It seems likely, therefore, that vulnerability reduction solutions might appeal to the large commercial market. Across the board, the light, capable, economic MANPADS have proven to be a real threat. ■

About the Author

Mr. Crosthwaite is director of the Survivability/Vulnerability Information Analysis Center (SURVIAC). He has worked on several technical analyses and test programs involving a wide variety of weapon systems. Mr. Crosthwaite has a M.S. in nuclear physics from Ohio State and is a licensed professional engineer. He serves on the ADPA Combat Survivability Division Executive Board and on the AIAA Survivability Technical Committee. He may be reached at 937.255.4840.

calendar of events

SEP

13–15 — Washington, DC
Aerospace Technology Exposition
AFA Annual Convention
Contact: 800.727.3337
www.jspargo.com/afa/start.htm

28–30 — Albuquerque, NM
AIAA Space Technology Conf. & Expo.
Contact: 703.264.7500
www.vs.afrl.af.mil/AIAA/

OCT

5–7 — Albuquerque, NM
Air Targets and UAVs
Contact: jhylan@ndia.org

26–28 — Fort Worth, TX
DIME, ESAMS Users Group Meeting
Contact: 937.255.4840, Geri Bowling

NOV

7–10 — Arlington, VA
DTIC Annual Users Meeting and Training Conference
Contact: 703.767.8236, Julia Foscue

16–18 — Monterey, CA
Aircraft Survivability 1999 Symposium
Contact: jhylan@ndia.org

30–2 Dec — Nellis AFB, NV
AIR-TO-AIR Meeting
Contact: 937.255.4840, Geri Bowling

DEC

14–16 — Charlottesville, VA
RADGUNS, ALARM, BLUEMAX Meeting
Contact: 937.255.4840, Geri Bowling
937.431.2707, Mike Bennet

Information for inclusion in the Calendar of Events may be sent to:

SURVIAC Washington Satellite Office
Attn: Christina McNemar
3190 Fairview Park Drive, 9th Floor
Falls Church, VA 22042

PHONE: 703.289.5464
FAX: 703.289.5467

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